

Noise in neonatal intensive care units: a short review

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Summary

Prematurity and low birth weight of newborns lead to the need of a special care in neonatal units, and their permanence in these places can be extended for a long period. Indoor environmental conditions, such noise levels above the recommended, may induce some risks, not only for the newborns development, but also for health care staff. This literature review aims to examine the studies related to noise in neonatal intensive care units to understand the sources and effects of noise, as well as some strategies to reduce noise exposure. The search strategy included an electronic search in databases (ISI Web of Knowledge and PubMed) of scientific articles published in English/Portuguese between 2000-2017. Studies providing data on noise levels found in the neonatal units, the effects on health of newborns and staff and the measures to minimize these effects were included. The exclusion criteria were as follows: duplicate printings; non-English/Portuguese language; editorials, letters, patents, errata, meeting abstracts and conference papers. PRISMA methodology was followed to perform the review. Twenty-two articles were considered for full analysis. It is important to note that some potentially relevant studies were rejected due to language criteria. It was found that the noise levels to which the newborns and staff are exposed in NICU, often exceeds the recommended levels for these spaces. Evidence also shows several adverse health effects for newborns and health care staff perceptions of noise. There is no consensus regarding the best intervention to reduce noise levels.

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1. Introduction

There is a growing concern about the fact that environmental conditions affect the well-being of patients, family members, and staff in hospitals. Perhaps nowhere in the healthcare environment is this more important than in neonatal intensive care units (NICU), where fragile infants fight for survival. The fragility of newborns, the increasing implementation of high-risk procedures and the low tolerance to medication errors are some of the concerns of health care professionals working in NICU (1). However, indoor environmental conditions may also induce some risks to the newborns development. Since infants in the NICU are constantly surrounded by high sound pressures levels, the acoustic environment of NICU and the potential auditory and non-auditory impact of excessive levels have been important topics of research for the past 20 years (2). There are recommendations and guidelines stating that a pressure level above 45 dBA can be harmful to the infant's ears and can affect their growth and development (2). In fact, the World Health

Organization (WHO) goes even further and recommend that the average background noise in hospitals should not exceed 35 dB LAeq for areas where patients are treated or observed (3).

The aim of the study was to examine the studies related to hospital noise in neonatal intensive care units (NICUs) to understand the sources and effects of noise and to describe best practices and strategies to reduce noise levels.

2. Methods

2.1. Bibliographic search

The identification and selection of studies to be included in the review was carried out through an extensive literature search using the PubMed and Web of Science databases. The search also included checking for related articles in the reference list of the located articles and other relevant literature. Only articles written in English and published in the

period from 2010 to the year 2017, were included. The last search date was August 8, 2017. The study was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) (4). The search strategy developed comprised two terms that were intersected using the Boolean term “AND”. Some of the searched terms were: „noise“, „NICU“, „workplace“, „premature infants“, „incubator“, „training“, or „noise reduction“.

2.2. Selection criteria

All searches were focused on in title or abstract. After importing all results into Mendeley, the articles were screened with respect to title, abstract and key words. The exclusion criteria were as follows: duplicate printings; non-English/Portuguese language; editorials, letters, patents, errata, meeting abstracts, and conference papers. Only peer-review articles reporting quantitative and/or qualitative assessment of sound pressure levels in NICU, focused on effects of noise on newborns and health care staff in NICU written in English/Portuguese, were included.

3. Results

The search strategy yielded a total of 104 citations before duplicates removal. After checking the duplicates, 92 papers were considered for screening. A total of 38 papers were deemed potentially relevant based on abstract. After application of the eligibility criteria while considering the full text, another 16 papers were excluded. A total of 22 studies were considered for the final analysis. Figure 1 displays the flowchart of the search strategy. The included studies refer to the noise levels in the NICU, the effects of noise on the health of both newborn and workers and measures to minimize it.

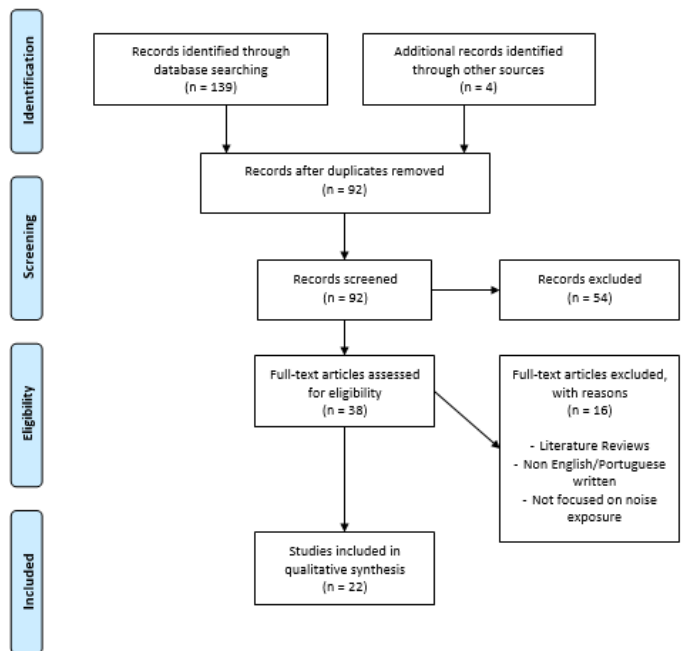


Figure 1. Flow diagram of the articles screening process.

4. Discussion

Noise levels in NICU

NICU are highly technically advanced, with enhanced ability to provide medical and nursing care. The uterus is not a quiet place, it has a rich soundscape with sounds coming mainly from the mother’s heart and blood vessels, who may even help the neurological development of babies and improve them of rhythm and melody understanding (5). However, in NICU environment there is an excessive level of noise (6). The NICU ambient noise is higher than in most homes or offices, and with newborns in contact with disturbing noises of short duration and at irregular intervals, it could cause increasing environmental stress (7). Ideally, in order to promote healthy hearing development, noise levels in the NICU should be identical in half intrauterine environment (8). Something that does not occur, because the noise produced by the operation of multiple devices combined with the conversations between professionals and the unexpected noise from procedures of this place (1,9,10). Noise levels at these locations range from 7 to 120 dB, which is a challenge for both the newborn as for the staff and parents (11). Evidence shows that noise often exceed the recommended 45dBA (1,9,12–17). Infant incubators are often used in NICU for care of newborns. They are made

to keep a child protected and designed with transparent sections to enable correct viewing, sensors and devices to monitor the vital status of the infant, and environmental controls for temperature, humidity, additional gas, among others. They are mainly used on premature infants with less than 37 weeks of gestation. These tools, along with the full range of services that NICU provide, have greatly increased the survival of many premature babies and low birth weight (5). However, many studies found high levels of noise within the incubators, which result in numerous adverse effects for health (18,19). These adverse health effects can have lasting consequences that compromise the quality of life of children who have gone through these treatment units (5). The noise in incubators is generated by equipment such as IV pumps, fans, warning sounds and heating machines. As this environment is closed, these sounds reverberate against the hard dome wall, amplifying the noise that reaches the neonate. In general, noise production in NICU rooms and inside incubators is usually due to alarms produced by life support devices, flow of medical gas, communication among professionals/visitors and during activities of nursing care (9). In fact, Carvalhais et al (1) performed a study, characterizing noise levels per health care activity. The tasks under study included administering medications, monitoring vital signs, providing hygiene and supplying vital nutrients to newborns. The noise levels ranged between 46.6 dBA to 74.6 dBA. Some published data revealed that low frequencies tend to have more influence on noise produced in the NICU than higher frequencies, with some exceptions due to loud midfrequencies alarms (9–11).

Effects of noise on newborns

The uterine environment provides high low-frequency sounds, with the maternal voice to stand out in the background sounds (20). On the other hand, the premature infant spends most of his early months in the incubator, exposed to continuous and unpredictable noise (6). The sensory nervous system of the newborn is able to capture the environmental stimuli and process them through the central nervous system. However, the organization of the central nervous system is immature so that the autonomous, motor and sensory functions are easily saturated (21).

The sound (especially when it is sudden and high) produces an alarm reaction characterized by

excitation of subcortical systems (particularly the amygdala), autonomic nervous system, somatic reflexes and hormonal regulation system (catecholamine corticosteroids secretion), may also be consequences for the respiratory system (22). Although these changes are rare, the exposure to noise can result in apnea and bradycardia, increasing the risks of hypoxic episodes and so impacting the recovery and survival of the vulnerable preterm infant. It has also been suggested that high noise levels may result in raised cortisol levels and lowered immunity, further compromising the medically fragile infant (23). Shimizu and Matuso (23) stated that noise exposure increases the risk of attention deficit disorder, and may result in tachycardia, bradycardia, increased intracranial pressure, and hypoxia. There is evidence that can cause sleep disorders and interfere with circadian rhythms (19).

Cardoso et al (24) conducted a study where were performed several noise measurements levels in a neonatal unit. They used a sample of 61 newborns that weight between 1000 and 2500g. In this study the environmental noise measurement occurred in two different moments: the usual situation in the NICU, that is, at the time of highest noise caused by a higher flow of people, use of equipment for clinical control, shift changes, medical visits, health care procedures; and during the “nap time”, where the health care staff decrease their activities, try not to talk, the parameters of devices with alarms are decreased, and the movement of people is also diminished. The study variables were the heart rate (HR) and oxygen saturation. The HR ranged from 137.74 beats per minute to 142.59 when the newborn infants were exposed to noise. Unlike the first variable, the oxygen saturation decreases with the noise, going from 95.58 to 94.96%. For the variable HR, a variation between 110 and 160 beats per minute can be notice, which is an important change considering the reference standard for newborns, even for underweight newborns, is a mean of 120 beats per minute. Another variable, O₂ saturation, which represents the percentage of inspired oxygen that reaches the more distant cells in the body, also shows a very significant variation, between 91 and 98%, considering that the normal level is 100%. There is evidence of deleterious effects of high levels of sound pressure occurring in newborns, for example, higher O₂ consumption and increase HR, which result in higher energy consumption (24). The cardiac response to acoustic stimulation depends on the behavioral state,

exposure history to sound based condition of the central nervous system, prenatal and perinatal events and age of the child after birth. The pressure of the active noise causes alterations on the hypothalamus and hypophysis and growth inhibitors are released, possibly through the action of corticosteroids (7). Hearing loss is diagnosed in 2% to 10% of premature infants against 0.1% of the general pediatric population (7). Despite that, evidence about non-auditory effects of exposure to environmental noise on public health is growing (25). Recent studies indicate that excessive exposure of newborns to noise can result in various psychological disorders that may have long-term effects on the nervous system.

Noise and healthcare staff

The work performed in NICU can be particularly psychologically demanding which combined with noise exposure within the NICU can increase the risk of work accidents occurrence, with negative consequences for staff and also for patients. In fact, noise may induce extra-auditory effects in professionals including burnout, stress, and fatigue (26). There is some association between noise and some health outcomes such increases in blood pressure, heart rate, hypertension, and other cardiovascular diseases. Noise exposure can also stimulate the release of epinephrine (adrenaline), increase pain, and alter quality of sleep (8,27). In general, evidence shows that technology together with the high number of health professionals within the NICU creates a busy and noisy environment (28). High noise levels are associated with an increased rate of errors and accidents, leading to decreased performance among employees (7,9,29). A study conducted by Morrison et al (30) studied the correlation between noise and nursing stress using a questionnaire and measuring salivary amylase and heart rate. This study concluded that noise is potentially a significant contributor to higher heart rates, and tachycardia among nurses, as well as nurses' stress and annoyance. Reported stress due to noise was closely correlated with predictors of burnout in these nurses. In NICU the heart rate nurses' goes from 67 to 184 beats per minute (16). A study conducted by Ryherd et al. (31), used a questionnaire to parse nurses' perception of noisy environments, and revealed that 91% of nurses felt that noise could negatively affect them in their routine work environment. It was also found that 66% of nurses felt irritation and fatigue,

43% had concentration problems, and 40% experienced tension headaches as an effect of noisy work environment. So it is possible to say that the nurses considered noise a disturbing agent with an associated negative impact (10). Santos et al (9) performed a questionnaire survey to assess noise perceptions of health professionals. Among the staff, 41.1% classified the environment (regarding noise) as "slightly uncomfortable"; 48.4% considered it as "acceptable." The majority (55.5%) considered "equipment" the most annoying source of noise. The study also comprised noise measurements, and results showed that noise levels were excessive in all the evaluated areas of the NICUs, exceeding international guidelines, with levels ranging between 48.7 dBA to 71.7 dBA. In fact, Basner et al (25) stated that noise levels in hospitals are now typically more than LAeq 15–20 dB higher than those recommended. Similar data were found in the majority of the studies.

Noise reduction strategies

Unfortunately, there are few studies developing methods, which are effective to reduce noise in NICU(5). Safe noise levels are essential for personal communication, family interactions and healthy child development, so it is important for practitioners to understand the current recommendations for the sound levels of these units (32). The results suggest that neonatal nurses have lack of expertise in noise prevention area, and that they would benefit by becoming involved in an educational program based on prevention of sound stimulation too much premature (21). Other measures that units can put into practice is easily gently close the doors of children's incubators– fix and move the pressure bottle of mechanical ventilator to outside the infant incubator. Several studies indicate that a major strategic to reduce noise is to change the behavior of health professionals (12,33,10,34–38). Brown(37) indicates several noise minimization measures to educate the multidisciplinary team and parents/visitors about the potential consequences of high noise levels and strategies for noise reduction, such: reduce conversation at the bedside and move and speak quietly; reduce alarm volumes; respond quickly to telephones, alarms, beeps, crying babies, and other disturbances; avoid putting things on top of incubators; close incubator portholes and drawers quietly; reduce telephone ringer volume; remove radios from the NICU; regularly remove

water from ventilator and CPAP tubing; cover incubators with thick blankets or cover to absorb sound; implement a quiet hour protocol; limit the use of the air conditioning system; reduce the volume of beeps or use the vibrating mode; minimize movement of personnel thorough and around NICU; avoid tapping and banging on incubators; avoid leaning on incubators to write; open packaging away from incubators, among others. A well-structured training program also seems to be a low cost measure to start the noise reduction process in the hospital(12). Altuncu et al (34), conducted a study where they measure the noise levels inside the incubator with and without absorbent panel sound (SAP). They prove that SAP reduce noise levels in infant's incubator and is an efficient measure to adopt. Another strategies are noise reduction guidelines, architectural changes, renovation and/or preventive maintenance of equipments, including parameters to the acquisition of equipments containing audible alarms (12). In fact, several studies have shown that the "private room" or single room NICU environment has been the most effective way to address sound issues, especially when used in conjunction with a cultural change among the staff (39,40).

5. Conclusions

Noise is an environmental stressor that is known to have physiological and psychological effects. The body responds to noise in the same way it responds to stress and overtime has potential to impair health. In general, vulnerable groups are underrepresented in study populations. Although anyone might be adversely affected by noise exposure (environmental or occupational exposure), a group that is particularly vulnerable is the premature infants/newborns group. In hospital environment, excessive noise is not only annoying, but can also interfere with the proper performance of health care. Evidence shows that hospital noise levels often exceed those recommended by WHO and other agencies.

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References

1. Carvalhais C, Silva M V, Xavier A, Santos J. Newborns Safety at Neonatal Intensive Care Units: Are they Exposed to Excessive Noise during Routine Health Care Procedures? *Global Health, Environment and Safety*. 2017; 1:1–3.
2. American Academy of Pediatrics: Committee on Environmental Health. Noise: A Hazard for the Fetus and Newborn. *Pediatrics*. 1997 Oct 1;100(4):724–7.
3. Berglund B, Thomas L, Dietrich HS. Guidelines for Community Noise. *Guidelines for Community Noise*. Geneva, Switzerland; 1999.
4. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009 Jul 21 [cited 2014 Jul 9];6(7):e1000097.
5. Yu X, Gujjula S, Kuo SM. Active Noise Control for Infant Incubators. 2009;2531–4.
6. Bremmer P, Byers JF, Kiehl E. Noise and the Premature Infant: Physiological Effects and Practice Implications. *J Obstet Gynecol Neonatal Nurs*. 2003;32:447–54.
7. Almadhoob A, Ohlsson A. Sound reduction management in the neonatal intensive care unit for preterm or very low birth weight infants. *Cochrane database Syst Rev*. 2015;1:CD010333.
8. Wachman EM, Lahav A. The effects of noise on preterm infants in the NICU. *Arch Dis Child Fetal Neonatal Ed*. 2011;96:F305–9.
9. Santos J, Carvalhais C, Xavier A, Silva M V. Assessment and characterization of sound pressure levels in Portuguese neonatal intensive care units. *Arch Environ Occup Health*, 2018 ;73(2):121-127. Epub 2017 Apr 5.
10. Carvalhais C, Santos J, Vieira M, Xavier A. Is There Sufficient Training of Health Care Staff on Noise Reduction in Neonatal Intensive Care Units? a Pilot Study From Neonnoise Project. 2015; 78:897-903.
11. Gray L, Philbin MK. Measuring sound in hospital nurseries. *J Perinatol*. 2000;20:S100–4.
12. Tsunemi MH, Kakehashi TY, Pinheiro EM. Noise at the neonatal intensive care unit after the implementation of an educational program. *Texto Context - Enferm*. 2012;21(4):775–82.
13. Pinheiro EM, Guinsburg R, Nabuco MA de A, Kakehashi TY. Noise at the Neonatal Intensive Care Unit and inside the incubator. *Rev Lat Am Enfermagem*. 2011;19(5):1214–21.
14. Kent WT, Tan AW, Clarke MC, Bardell T. Excessive noise levels in the neonatal ICU: potential

effects on auditory system development. *J Otolaryngol.* 2002;31:355–60.

15. Hassanein SMA, Raggal NM El, Shalaby AA. Neonatal nursery noise : practice-based learning and improvement. 2013;26(4):392–5.

16. Watson J, Kinstler A, Vidonish WP, Wagner M, Lin L, Davis KG, et al. Impact of Noise on Nurses in Pediatric Intensive Care Units. *Am J Crit Care.* 2015 ;24(5):377–84.

17. Peixoto PV, Araújo MAN de, Kakehashi TY, Pinheiro EM. Nível de pressão sonora em Unidade de Terapia Intensiva Neonatal . Vol. 45, Revista da Escola de Enfermagem da USP. 2011. p. 1309–14.

18. Pinheiro EM, Guinsburg R, Antonio M, Nabuco DA, Kakehashi TY. Noise at the Neonatal Intensive Care Unit and inside the incubator. 2011;19(5):1214–21.

19. Trapanotto M, Benini F, Farina M, Gobber D, Magnavita V, Zacchello F. Behavioural and physiological reactivity to noise in the newborn. 2004;275–81.

20. Philbin MK, Klaas P. Evaluating studies of the behavioral effects of sound on newborns. *J Perinatol.* 2000;20:S61–7.

21. Aita M, Goulet C. Assessment of neonatal nurses’ behaviors that prevent overstimulation in preterm infants. *Intensive Crit Care Nurs.* 2003;19(2):109–18.

22. Freedman NS, Gazendam J, Levan L, Pack AI, Schwab RJ. Abnormal sleep/wake cycles and the effect of environmental noise on sleep disruption in the intensive care unit. *Am J Respir Crit Care.* 2001;163.

23. Shimizu A, Matsuo H. Sound Environments Surrounding Preterm Infants Within an Occupied Closed Incubator. *J Pediatr Nurs.* 2016;31(2):e149–54.

24. Cardoso SMS, Kozlowski L de C, de Lacerda ABM, Marques JM, Ribas A. Newborn physiological responses to noise in the neonatal unit. *Braz J Otorhinolaryngol.* 2015;81(6):583–8.

25. Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, et al. Auditory and non-auditory effects of noise on health. Vol. 383, *The Lancet.* 2014. p. 1325–32.

26. Mahmood A, Chaudhury H, Valente M. Nurses’ perceptions of how physical environment affects medication errors in acute care settings. *Appl Nurs Res.* 2011;24:229–37.

27. Ceylan N, Kaba S, Karaman K, Celiker M, Basbugan Y, Demir N. Investigation of the effect of the efficiency of noise at different intensities on the DNA of the newborns. *Noise Health.* 2016;18(80):7–9.

28. Elliott RM, McKinley SM, Eager D. A pilot study of sound levels in an Australian adult general intensive care unit. *Noise Health.* 2010;12:26–36.

29. Nunes C, Santos J, da Silva MV, Lourenço I, Carvalhais C. Comparison of different methods for work accidents investigation in hospitals: A Portuguese case study. *Work A J Prev Assess Rehabil.* 2015;51(3):601–9.

30. Morrison WE, Haas EC, Shaffner DH, Garrett ES, Fackler JC. Noise, stress, and annoyance in a pediatric intensive care unit. 2003;31(1):113–9.

31. Ryherd EE, Wayne KP, Ljungkvist L. Characterizing noise and perceived work environment in a neurological intensive care unit. *J Acoust Soc Am* [Internet]. 2008;123(2):747–56. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/18247879>

32. Brown G. NICU Noise and the Preterm Infant. *Neonatal Netw J Neonatal Nurs.* 2009 May 1;28(3):165–73.

33. Zamberlan-Amorim NE, Fujinaga CI, Hass VJ, Fonseca LMM, Fortuna CM, Scochi CGS. Impact of a participatory program to reduce noise in a Neonatal Unit. *Rev Lat Am Enfermagem.* 2012;20(1):109–16.

34. Altuncu E, Akman I, Kulekci S, Akdas F, Bilgen H, Ozek E. Noise levels in neonatal intensive care unit and use of sound absorbing panel in the isolette. *Int J Pediatr Otorhinolaryngol.* 2009;73(7):951–3.

35. Pai JY. A study in hospital noise - a case from Taiwan. *Int J Occup Saf Ergon.* 2007;13(1):83–90.

36. Chen H-L, Chen C-H, Wu C-C, Huang H-J, Wang T-M, Hsu C-C. The Influence of Neonatal Intensive Care Unit Design on Sound Level. *Pediatr Neonatol.* 2009;50(6):270–4.

37. Brown G. NICU Noise. 2008;(April):165–73.

38. Cardoso SMS, Kozlowski L de C, de Lacerda ABM, Marques JM, Ribas A. Newborn physiological responses to noise in the neonatal unit. *Braz J Otorhinolaryngol.* 2015;81(6):583–8.

39. Liu W. Comparing sound measurements in the single-family room with open-unit design neonatal intensive care unit: the impact of equipment noise. *J Perinatol* [Internet]. 2011;32(10):368–73.

40. Stevens D, Khan MA, Munson D, Reid E, Helseth C, Buggy J. The impact of architectural design upon the environmental sound and light exposure of neonates who require intensive care: an evaluation of the Boekelheide Neonatal Intensive Care Nursery. *J Perinatol.* 2007;27:20–8.